

Radiation in the NuMI Stub at Beam Accidents in the Main Injector

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1 Beam accident scenarios

One needs to know the radiation dose behind a 30-foot shielding wall in order to evaluate access conditions to the NuMI stub with the Main Injector operating. A calculation model was set up within the MARS framework [1]. The model covers the Main Injector extraction region and the NuMI tunnel down to the MINOS target hall. No NuMI beam elements were put into the model. The 30-foot shielding wall was placed into a new position that is 40 feet upstream with respect to its old one. The proton intensity was assumed to be 2×10^{13} ppp.

Two types of a beam accident are studied. The first one is an accident at injection at the first turn. A 8 GeV kinetic energy proton beam is lost due to a magnet failure. That may happen if a magnet fails to ramp up after being shut down. This scenario would lead to a local loss of the full beam within several meters.

The second type of a beam accident is the one at 120 GeV. The beam loss due to a magnet failure becomes quite impossible. The reason is that a magnet can be completely turned off only within ~ 5 msec. This time is given by the induction of electric chain supplying the Main Injector magnets. The reaction time of the beam abort system is of the order of $\sim 50 \mu sec$, so that the beam is aborted before it is lost locally. The most probable considered place for losses is one of the quadrupoles, i.e. elements where the beam amplitude is maximal. One can imagine a situation where due to some beam instability there is a continuous amplitude growth. The beam is lost then in one of the quadrupoles during several beam turns. Although only a part of the beam can be lost this way since the beam abort system still should work, one makes a conservative estimate assuming that the entire beam is lost.

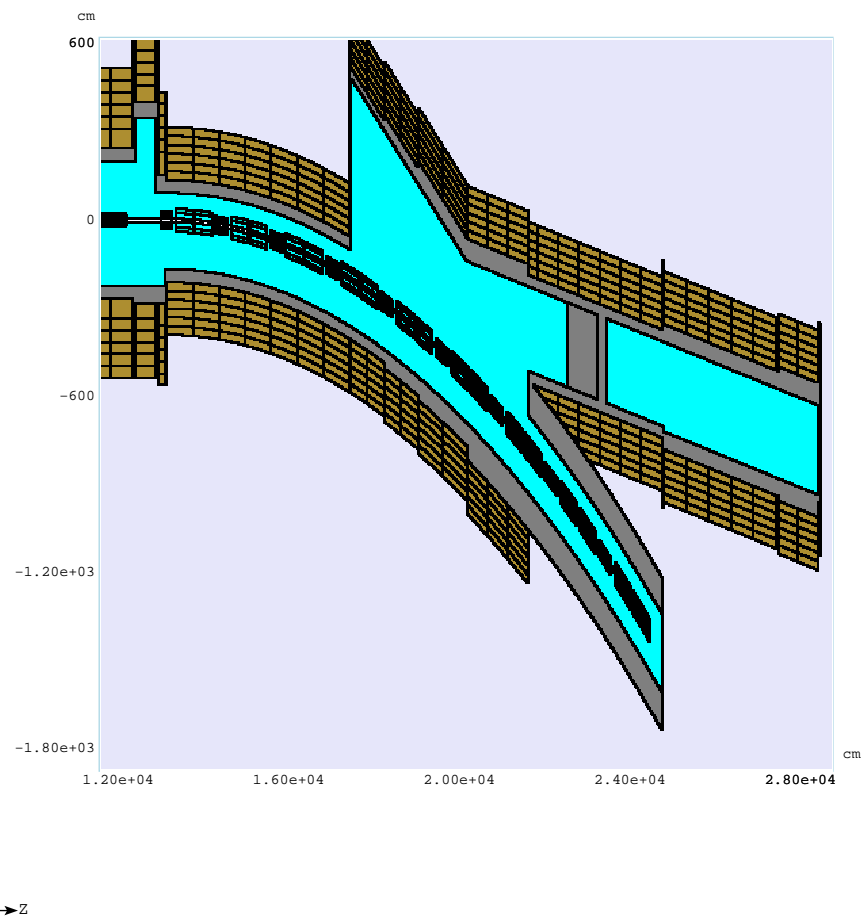


Figure 1: Part of the Main Injector and NuMI tunnel described in MARS.

2 8 GeV beam loss

The entire section of the coded part of the Main Injector was scanned for the magnet failure. It has been found that the worst case corresponds to the failure of the dipole IDC027, that is the 7th dipole downstream of the Lambertson magnets. Such a failure provides geometrically favorable conditions for secondary particles generated in the initial 8 GeV beam interactions with material of the beamline elements to head towards the 30-foot shielding wall. The dose equivalent averaged over a tissue equivalent phantom at the hottest spot downstream of the wall is $(5.10 \pm 0.37) \times 10^{-4}$ mSv/pulse. The dose upstream of the wall is 26.56 ± 1.17 mSv/pulse.

3 120 GeV beam loss

Several quadrupoles were tested for the beam losses. At first, multi-turn beam losses were simulated with the STRUCT code [2] then the lost protons were fed to the MARS model. It has been found that the highest dose downstream of the shielding wall is obtained at the accident in the defocusing quadrupole Q613. Similarly to the 8 GeV case, this type of accident provides geometrically favorable conditions for the beam interaction products to reach the 30-foot shielding wall. The dose equivalent for this case is shown in Fig. 2. The dose averaged over a phantom at the hottest spot is 0.13 ± 0.01 mSv/pulse. The dose upstream of the wall is 28.42 ± 3.53 mSv/pulse.

At 120 GeV, the dose downstream of the wall is dominated by muons. This is not the case for an 8 GeV accident, because only muons with energy more than ~ 5 GeV can penetrate through the wall. The fraction of such muons for an 8 GeV beam accident is negligible.

References

- [1] N.V. Mokhov, "The MARS Code System User's Guide", Fermilab-FN-628 (1995); N.V. Mokhov, O.E. Krivosheev, "MARS Code Status", Proc. Monte Carlo 2000 Conf., p. 943, Lisbon, October 23-26, 2000; Fermilab-Conf-00/181 (2000); <http://www-ap.fnal.gov/MARS/>.
- [2] I.S. Baishev, A.I. Drozhdin and N.V. Mokhov, "STRUCT Program User's Reference Manual", SSCL-MAN-0034 (1994).

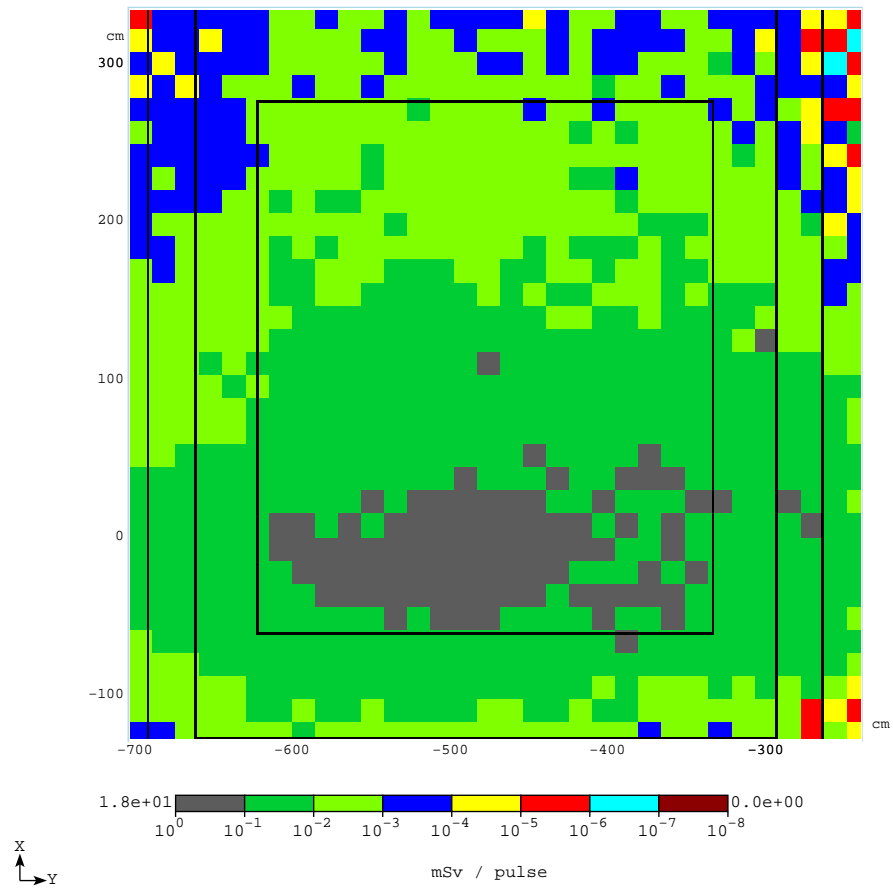


Figure 2: Dose equivalent downstream of the 30-foot shielding wall after the worst case accident at 120 GeV.